ATTACHMENT A

TSB86

TIA/EIA TELECOMMUNICATIONS SYSTEMS BULLETIN

Criteria and Methodology to Assess Interference Between Systems in the Fixed Service and the Mobile-Satellite Service in the Band 2165-2200 MHz

TSB86

OCTOBER 1999

TELECOMMUNICATIONS INDUSTRY ASSOCIATION

Representing the telecommunications industry in association with the Electronic Industries Alliance

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PREFACE

TERMS AND DEFINITIONS

SECTIONS

Preface

This Telecommunications System Bulletin (TSB-86) was prepared by a Joint Working Group (JWG), comprised of TR-34.2, TR-14.11 and the National Spectrum Managers Association. The JWG, designated JWG TR-34.2/TR-14.11/NSMA, was formed under the auspices of the TIA following a number of informal discussions among representatives of the mobile satellite and terrestrial fixed microwave point-to-point service industries, TIA officials and other interested parties.

The 2165 – 2200 MHz band has been allocated by the FCC for the Mobile Satellite Service (MSS) (space-to-Earth) on a co-primary basis with the Fixed Service (FS) commencing on January 1, 2000. The band is currently used by Common Carrier microwave and Private Operational Fixed Service microwave operators; and, one of the key issues in the FCC's 2 GHz Rulemaking is the extent to which this band can be shared between the MSS and these FS users.

The Satellite Communications Division and Wireless Communication Division of TIA agreed to form the JWG with Terms of Reference as follows:

1. Study the potential for sharing the band 2165-2200 MHz between satellite systems operating in the MSS and microwave systems operating in the FS;

2. Determine the conditions under which sharing may be possible and the arrangements necessary for sharing to occur (if any);

3. Document the essential elements of the study with findings and conclusions that can be assessed by others not directly involved in the study and produce a TSB to be published by the TIA;

4. Follow the prescribed TIA rules of procedure (TIA Chair's Procedures Notebook), Legal Guide, Engineering Manual and other TIA guidance appropriate for the type of product being developed.

This TSB-86 is primarily intended to provide a methodology for evaluating MSS interference into FS receiving stations. In publishing this TSB, the JWG makes no claims or conclusions about the extent to which the 2165-2200 MHz band can be shared between MSS and FS users.

The primary output of the JWG is this TSB-86, which draws upon material in TSB-10F. Consequently, the reader should have access to TIA TSB-10F and refer to that document when necessary. Also, where applicable, references to certain ITU-R Recommendations and citations to the ITU Radio Regulations are made in order to conserve space; these references are available through the internet by consulting the ITU's web site (http://www.itu.int). The reader/user of this document is advised that the methodologies presented in Section 4 of the instant version of TSB-86 are valid only for evaluating MSS interference into FS receive stations *not* operating with Automatic Transmit Power Control (ATPC). A significant percentage of FS stations may operate with ATPC. Finally, terrain scatter is not explicitly considered in this TSB (see Section 1.3).

1. Criteria & Methodology to Assess Interference between Systems in the Fixed Service and the Mobile-Satellite Service in the 2165-2200 MHz Band

1.1 Introduction

This document provides technical background information on systems operating in the FS and the MSS in the 2.1 GHz frequency band (Section 2); delineates methods for evaluating the associated potential interference (Sections 3, 4 and 5); presents example applications for the methodology (Section 6) and discusses possible interference mitigation techniques (Section 7). Effective January 1, 2000, the frequency band 2165-2200 MHz will be allocated in the United States and Canada to both the FS and MSS (space-to-Earth).[1] However, in accordance with the ITU Radio Regulations (RR), the subject frequency sharing situations can also arise in the 2160-2165 MHz band. General background information on international and domestic coordination of proposed 2 GHz MSS systems (with terrestrial FS) is provided in the subsequent sub-sections.

1.2 Frequency Coordination

As of December 15, 1998, the MSS networks listed in Table 1-1 and Table 1-2 have been "Advanced Published" with the International Telecommunication Union (ITU) for operation in the band 2160-2200 MHz. Operators of some, but not necessarily all of these systems have applied to the FCC to serve mobile terminals in the United States. This fact notwithstanding, foreign MSS networks can potentially cause interference to US FS systems whether or not they are providing service within the US.

As illustrated in Figure 1-1, the FCC, on behalf of the US FS operators, can request coordination in cases where either the power flux density (PFD) or fractional degradation in performance (FDP) thresholds for coordination are exceeded and, if applied, the Standard Computation Program (SCP) indicates that the applicable interference thresholds are exceeded. The methodology presented herein for evaluating potential interference is consistent with the RR coordination procedures and will be useful to the US FS community in support of its international frequency coordination endeavors.

In order to accrue US rights to use the 2165-2200 MHz MSS resources, the FCC has Advanced Published with the ITU certain of the MSS systems listed in Tables 1-1 and 1-2 (i.e., the systems for which "USA" is listed as the administration). These systems are representative of anticipated US MSS systems. The methodology presented is for evaluating potential interference between MSS and FS systems. The FCC has received nine applications to use 2165-2200 MHz MSS resources in the United States.

[1] FCC, ET Docket No. 95-18 (FCC 2 GHz Order), released March 14, 1997. Also see FCC, ET Docket No.95-18, Memorandum Opinion and Order & Third NPRM and Order, released November 25, 1998.

In addition, foreign MSS networks have been "Advanced Published" with the International Telecommunications Union (ITU) that will not provide services in the United States. This notwithstanding, the downlink frequency assignments for these satellites might be capable of causing interference to US FS systems and are subject to the bilateral frequency coordination provision of RR No. S9.11A and Appendix S5 (formerly Annex 2 to RR Resolution 46).

Tables 1-1 and 1-2 provide a listing of the MSS networks that have been Advanced Published with the ITU for operation in the band 2160-2200 MHz as of December 15, 1998.

Table 1-1 Non-GSO MSS Systems Advanced Published with the ITU at 2 GHz (as of 15 December 1998)

NETWORK	ADMININISTRATION
QUASIGEO-L3	Germany
F-SAT ICO	France
F-SAT LEO	France
F-SAT LEO-A	France
ICO-P	United Kingdom
PETALRING 60E-S	Netherlands
PETALRING 30C-S	Netherlands
MEASAT-LEO	Malaysia
MEASAT-MEO	Malaysia
SIGNAL	Russia
TONGASAT-LEO-10000	Tonga
TONGASAT-LEO-1200	Tonga
TONGASAT-LEO-1300	Tonga
TONGASAT-ELL-1	Tonga
MSS-LEO-1	USA
MSS-LEO-2	USA
MSSLEO-4B	USA
MSSLEO 3	USA
MSSLEO-4A	USA
MSSLEO-2A	USA
MSSLEO-5	USA

Table 1-2 GSO MSS Systems Advanced Published with the ITU at 2 GHz (as of 15 December 1998)

NETWORK	ADMINISTRATION	LOCATION
INTERSPUTNIK-6W	Belarus/IK	6W
INTERSPUTNIK-16W	Belarus/IK	16W
INTERSPUTNIK-17E	Belarus/IK	17E
INTERSPUTNIK-27E	Belarus/IK	27E
INTERSPUTNIK-64.5E	Belarus/IK	64.5E
INTERSPUTNIK-67.5E	Belarus/IK	67.5E
INTERSPUTNIK-114.5E	Belarus/IK	114.5E
INTERSPUTNIK-3W	Belarus/IK	3W
INTERSPUTNIK-23W	Belarus/IK	23W
INTERSPUTNIK-32.5W	Belarus/IK	32.5W
INTERSPUTNIK-153.5E	Belarus/IK	153.5E
INTERSPUTNIK-97W	Belarus/IK	97W
INTERSPUTNIK-83W	Belarus/IK	83W
INTERSPUTNIK-59.5E	Belarus/IK	59.5E
INTERSPUTNIK-75E	Belarus/IK	75E
CANSAT-M3	Canada	106.5W
KYPROS-SAT-L1	Cyprus	27.5E
KYPROS-SAT-L2	Cyprus	30E
KYPROS-SAT-L3	Cyprus	37E
KYPROS-SAT-L4	Cyprus	39E
SATPHONE-1	Germany	29E
SATPHONE-2	Germany	52E
GARUDA-1	Indonesia	118E
GARUDA-2	Indonesia	123E
GARUDA-3	Indonesia	135E
GARUDA-4	Indonesia	80.5E
DACOMSAT-11LSC	Korea	155E
DACOMSAT-8LSC	Korea	107E
DACOMSAT-9LSC	Korea	109E
HYUNDAI-AS	Korea	120E
HYUNDAI-BS	Korea	126E
ST-2A	Singapore	88E
ST-2B	Singapore	98.5E
EMARSAT-1A/M	UAE	24E
EMARSAT-1B/M	UAE	54E
EMARSAT-1F	UAE	44E

EMARSAT-1G	UAE	51.5E
EMARSAT-1J	UAE	33.5E
EMARSAT-1K	UAE	38.5E
EMARSAT-1L	UAE	28.5E
AGRANI-1	UK	11.5E
AGRANI-1A	UK	29E
AGRANI-2	UK	52E
AGRANI-2A	UK	46E
AGRANI-3	UK	120E
AGRANI-3A	UK	80E
EAST-10E	UK	10E
EAST-13E	UK	13E
EAST-16E	UK	16E
EAST-22E	UK	22E
EAST-6E	UK	6E
EAST-1	UK	32E
INMARSAT-GSO-2A	UK/Inmarsat	90W
INMARSAT-GSO-2B	UK/Inmarsat	88W
INMARSAT-GSO-2C	UK/Inmarsat	21.5E
INMARSAT-GSO-2D	UK/Inmarsat	20E
INMARSAT-GSO-2E	UK/Inmarsat	109E
INMARSAT-GSO-2F	UK/Inmarsat	110E
INMARSAT-GSO-2G	UK/Inmarsat	166W
INMARSAT-GSO-2H	UK/Inmarsat	170W
UKRSAT-4S-64.5E	Ukraine	64.5E
UKRSAT-5 S 38.2W	Ukraine	38.2W
USASAT-27B	USA	76W
USASAT-27C	USA	96W
USASAT-27D	USA	116W
USASAT-27E	USA	101W
USASAT-27G	USA	100W
USASAT-27H	USA	170W
USASAT-27I	USA	76W
USASAT-27K	USA	116W
USASAT-27J	USA	76W
USASAT-27F	USA	10E

1.3 Nature of Interfering Signals from Mobile-Satellite Service Networks

As can be seen from Tables 1-1 and 1-2, MSS systems planning to operate downlinks in the band 2160-2200 MHz utilize either geostationary (GSO) or non-geostationary (non-GSO) satellites. Signals from a GSO satellite produce a PFD that has a nominally fixed angle of arrival at an FS antenna, and the magnitude of the PFD may vary as a result of changing downlink traffic channel assignments (loading), the effect of power control on individual channels, and channel activity (e.g., if voice activated carriers are used). Additionally, for non-GSO satellites, the motion of the satellites introduces a major cause of variation in the interfering signal power received by an FS station. Although interfering emissions from satellites may enter FS receivers through scatter or reflection from terrain features, this mechanism has not been considered in the past in determining the interference potential of emissions from geostationary satellites, nor has it been found to be a problem in bands currently shared between the FS and GSO satellites. It is expected that energy coupled by this mechanism would contribute to the variability of the interference, rather than to an increase in the interference power level. Consequently, terrain scatter is not explicitly considered in this issue of this Bulletin.

The influence of MSS loading, power control, and channel activity in GSO and non-GSO systems depends on the MSS modulation and multiple access technique and the reference bandwidth used in the analysis. Numerous narrow-band MSS channels overlapping an FS channel may produce an average level of interfering signal power that has a low variance over time periods of tens of seconds in accordance with the central limit theorem of statistics. However, there is a large variation in this signal level over much longer time periods as a result of variations in loading, and, in the case of non-GSO MSS satellites, as a result of varying antenna discrimination at the satellite and FS station. Thus, the average interfering signal power level from narrow-band MSS systems is determined based on the number of overlapping MSS channels and their individual power levels. These two considerations encompass the effects of channel guard bands as well as loading and channel activity. Wide-band MSS systems (e.g., those using spread spectrum modulation and CDMA) produce an average interfering signal level that exhibits low variance over small time intervals but substantial variation over larger time intervals due to varying traffic loading (and varying antenna discrimination in the case of non-GSO satellites).

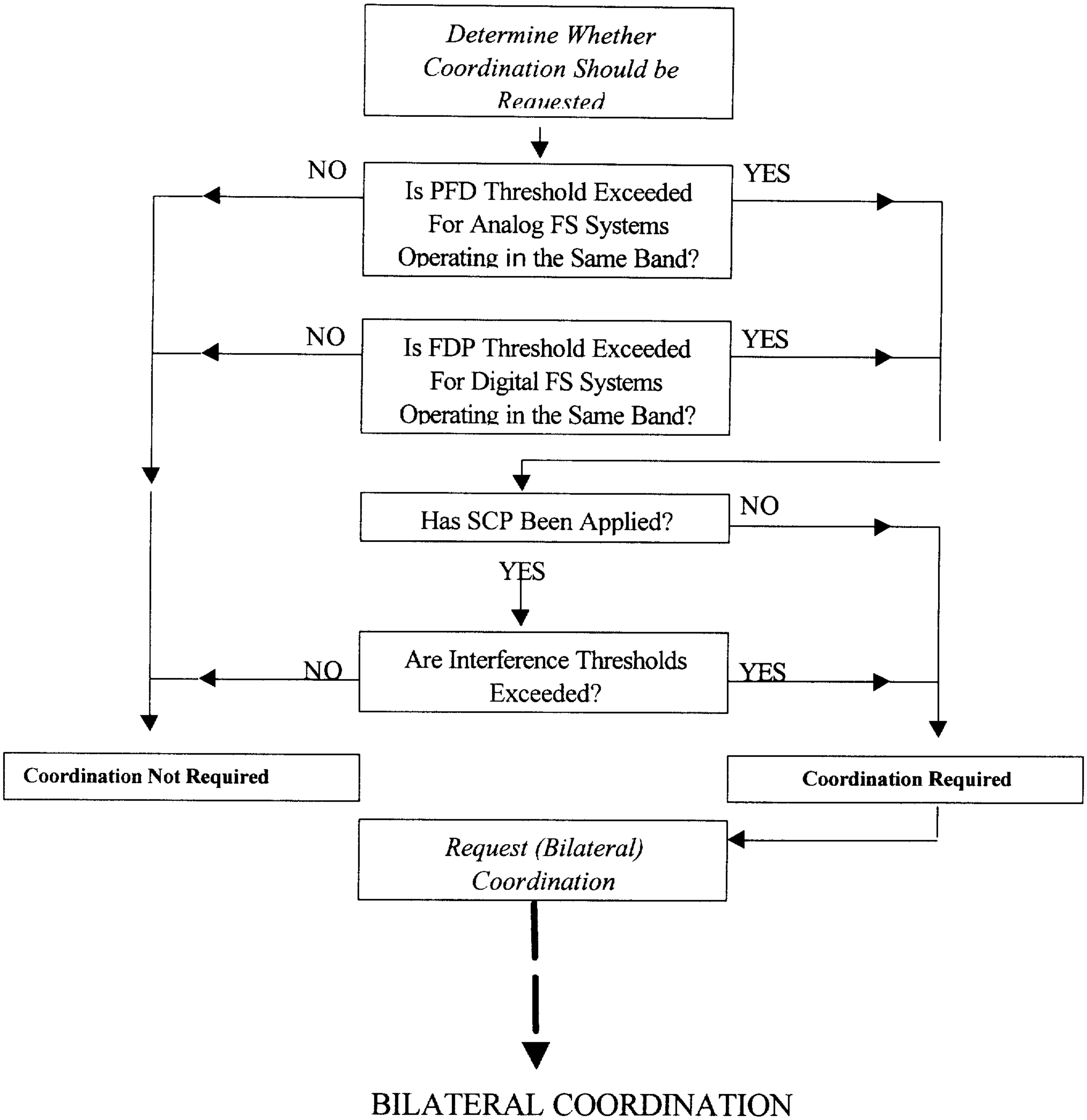

Figure 1-1. Technical Elements of ITU RR Provisions Relevant to International Coordination of Assignments for MSS Systems in the 2160-2200 MHz Band

2. Typical System Characteristics

2.1 Introduction

This section summarizes the characteristics of fixed service point-to-point systems (both analog and digital) and mobile satellite systems in the 2.110-2.200 GHz bands.

2.2 Fixed Service System Characterization in the 2.11 - 2.20 GHz Frequency Band.

The 2110-2150/2160-2200 MHz frequency range is currently used by two separate services. These services are Common Carrier (CC) (formerly Part 21) users, and Private Operational Fixed Service (POFS) (formerly Part 94) users (CFR Part 101). The frequency band allocations and channel bandwidths are as follows:

Frequency Range (GHz)	Bandwidth	Users
2.11-2.13 & 2.16-2.18	3.5/3.6 MHz	CC
2.13-2.15 & 2.18-2.20	0.8/1.6 MHz	POFS

The CC users are primarily cellular radio providers who are using the microwave radios for cell site interconnection. There are a few Common Carrier telephone companies that also use 2 GHz microwave radios for low capacity needs in their networks. The microwave radios in the Common Carrier bands are primarily digital radios with capacities of 2-, 4-, 8-, and 12-DS1s.

The 2.1 GHz POFS band encompasses a large variety of different users and applications. State and local governments (including public safety), railroads, pipelines, and electric utilities are the majority of the users. There are also some corporate networks utilizing microwave radios in this band. The microwave radios used in the Private bands are primarily analog radios, though many of these analog radios employ digital modems with modulation complexities of up to 256 QAM to provide data traffic over the analog network. These analog radios have capacities ranging from 24 to 96 voice channels.

2.2.1 Characteristics of Analog Radios in the 2.1 GHz band.

Table 2-1 summarizes the most commonly used analog radios in the 2.1 GHz POFS band.

Table 2-1 Commonly used radios in the 2.13-2.15 and 2.18 - 2.20 GHz (private) band

Radio Model	Voice Channel Capacity & Bandwidth (MHz)	Transmit Power (dBm)	Receive Threshold (dBm)	Critical C/I (dB)	Modulation	Usage %
Granger						
HR2.1	96 (1.6)	33	-88	18	FM/FDM	0.7
Harris						
LR1-2	48 (0.8)	29/36	-87.5	16	FM/FDM	14.4
LR1-2	96 (1.6)	29/36	-87	17	FM/FDM	12.4
TR2000-R	24 (0.8)	33	-88	14	FM/FDM	1.5
Lenkurt						
70F1	48 (0.8)	30	-89	11	FM/FDM	1.7
70F2	96 (1.6)	30	-87	12	FM/FDM	2.0
70F3	96 (1.6)	30	-88	13	FM/FDM	1.4
Motorola						
CC6001	48 (0.8)	21/31	-88.5	13	FM/FDM	17.5
CC6001	96 (1.6)	21/31	-87.5	18	FM/FDM	30.2
MA373	48 (0.8)	37	-83	20	FM/FDM	2.5
Western Multiplex						
HZB-12000	96 (1.6)	30/37	-88	14	FM/FDM	1.0

2.2.2 Characteristics of Digital Radios in the 2.1 GHz band.

Table 2-2 illustrates the wide variety of commonly used digital radios in the 2.1 GHz Common Carrier bands. This is not an all-inclusive list.

Table 2-2 Commonly used radios in the 2.11-2.13 and 2.16 - 2.18 GHz (common carrier) band

Radio Model	Channel Capacity	Transmit Power (dBm)	Receive Threshold (dBm)	Critical C/I (dB)	Modulation	Usage %
Alcatel						
MDR-5102	12 T1	28/30/32*	-72.5	33	256 QAM	5.5
MDR-5202	8 T1	30/32/35*	-80	26.6	64 QAM	4.7
MDR-5302	4 T1	30/32/35*	-83	26.6	64 QAM	6.6
Tadiran						
DR2C	4 T1	20/27/32	-86	16	QPR-3	5.4
DR2L	4 T1	20/27/31	-88	18	QPR-3	3.8
DR2D	8 T1	20/23/29.5 /32	-78	22	QPR-7	18.1
2G-4DS1	4 T1	24/30**	-87.5	18.3	8 QAM	4.5
2G-8DS1	8 T1	24/30**	-82.5	24.5	32 QAM	2.8
2G-12DS1	12 T1	21/27**	-75.5	30.3	128 QAM	2.8
Harris						
DM2-3A-6	4 T1	21/29	-84	14	9 QPRS	5.7
DM2-4A-12	8 T1	33	-80	21	16 QAM	2.4
DVM2-8T	8 T1	21/29	-77.5	24.6	49 QPRS	16.4

Notes:

1. The multiple power levels shown in the 3rd column are the different output full-power options.
2. Non-starred (*) power levels do not have ATPC capability in this frequency band.

* All Alcatel radios have ATPC capability,

** These Tadiran radios only operate under ATPC.

As shown in Table 2-2, many digital radios shown above can operate under ATPC (Automatic Transmit Power Control), although the degree to which this option is implemented has not been studied. In systems implementing ATPC, the radios are backed-off from their maximum transmit power by 6-10 dB minimum (ATPC-equipped Tadiran radios are backed off 6 dB, Alcatel radios are backed off 10 dB). Radios using ATPC are operating at a C/N level that is less than that associated with operation of the transmitter at a constant, peak power level. Under ATPC conditions, transmitter power is increased when the desired signal fades to some predetermined fade depth. For Alcatel radios, the transmitter power begins to increase linearly with fade depth when the far-end receivers fade below -65 dBm. The ATPC-equipped Tadiran radios increase their power in a single step when their far-end receivers fade to wthin 15 dB of receive threshold and the BER is 10^{-11}. In all cases, whether the path was coordinated under ATPC rules or not, the users may be using ATPC since its implementation reduces radio power consumption, thereby both enhancing equipment reliability and reducing air conditioning and battery plant requirements.

The 2.1 GHz band has been extremely popular for cellular users because it was the only low-capacity band available before the release of FCC Part 101. Additionally, since there are no FCC antenna performance requirements below 2.5 GHz, these FS sites tend to employ low wind resistance monopole towers instead of more expensive guyed towers. Grid antennas as small as four feet in diameter are in use. The table below shows the characteristics of some of the grid antennas used in this band.

Diameter	Gain	Beamwidth	Cross-Polarization Discrimination	Front-to-Back Ratio
4 ft	26.1 dB	8.1 deg	32 dB	34 dB
6 ft	29.9 dB	4.9 deg	34 dB	39 dB
8 ft	32.2 dB	4.0 deg	37 dB	40 dB

High-performance antennas have the same gain and beamwidth values, but they have 23-25 dB better front-to-back ratios.

2.3 Mobile-Satellite Service System Characteristics

A number of MSS systems have been proposed to provide data and telephony services in the 2 GHz bands, as shown in Table 2-3. Table 2-3 provides representative MSS system characteristics which have been extracted from the license applications. In some cases, specific values are still being finalized and could be subject to change pending ongoing FCC processes. The specific MSS system operator should be contacted to determine the actual (updated) required operational parameters.

All of the systems, except for the Boeing MSS system, are being developed to provide services to terrestrial-based mobile and portable terminals. The Boeing MSS system is being developed to provide aeronautical communications, navigation, and surveillance services for global avionics. Thus, for the Boeing MSS system, the user terminal would be located on an aircraft.

As shown in Table 2-3, the proposed MSS systems comprise a wide spectrum of constellation designs, including both GSO and non-GSO configurations. In the case of the Ellipso 2G system, elliptical orbits have been proposed. All of the MSS systems employ multiple beam-type antennas having up to several hundred beams. The antenna polarizations used in any given MSS system are exclusively circular (depolarization due to signal propagation phenomena prevents the use of linear polarization or both circular polarizations). A variety of multiple access schemes have been proposed including time division multiple access (TDMA), code division multiple access (CDMA), frequency division multiple access (FDMA) and multiple combinations.

Mobile satellite systems operating in the 1-3 GHz range must share the available spectrum with a number of other MSS systems. In order to efficiently use the limited resource, MSS systems are designed to re-use the frequency spectrum by employing mulitple beam satellite antennas. Frequency re-use is achieved by assigning the same frequencies (or frequency blocks) to several spot beams in a cellular frequency assignment scheme. Any two co-frequency spot beams must have sufficient isolation to ensure an adequate carrier-to-interference ratio. An example of a multiple-beam satellite antenna, employing a four-cell frequency re-use scheme is shown in Annex K.

Table 2-3: Representative Mobile Satellite Service (MSS) System Characteristics

Category	Parameters	Iridium (Macrocell)	Globalstar (GS-2)	ICO	Boeing (Note 2)
Constellation	Orbit	Circular	Circular	Circular	Circular
	Inclination	98.8°	54° for non-GSO	45°	53°
	# Satellites	96	64 non-GSO; 4 GSO – preferably 80° W, 10°E, 100° E and 170°W	10 to 12	16
	# Planes	8	8 for non-GSO	2	16
	Satellite Separation	30°		60° for 12 satellite configuration; 72° for 10 sat configuration	N/A
	Altitude (km)	850 (nom)	1420 for non-GSO, 35750 (nom) for GSO	10,355	20,181
Space Station Design	Antenna Type	Multiple Beam Antenna	Multiple Beam Antenna	Multiple Beam Antenna	Multiple Beam Antenna
	# Beams	228	non-GSO: 96 GSO: 64	163	37
	Polarization	RHCP	LHCP	RHCP	RHCP and LHCP
User Terminal Design (Note 3)	Antenna Type	Non-Directional	Non-Directional	Non-Directional	Non-Directional
	Receive G/T (dB/K)	-24.8	-24.5 (derived)	-23.8	ATN: -17.55 (derived) TIS: -19.3
S-E Service Link Parameters	Access Scheme	Data: CDMA/FDMA Voice: TDMA/FDMA	CDMA/FDMA & TDMA/FDMA	TDMA/FDMA	ATN: CDMA TIS: TDMA/FDMA
	Frequency (GHz)	Uplink: 1.990 – 2.025 Dnlink: 2.165 – 2.200	Uplink: 1.990 – 2.025 Dnlink: 2.165 – 2.200	Uplink: 1.985 – 2.015 Dnlink: 2.170 – 2.200	Uplink: 1.990 – 1.99825 Dnlink: 2.170 – 2.17825
	Modulation	QPSK	QPSK	QPSK	ATN: Same as IS-95A TIS: QPSK

Table 2-3 (Continued): Representative Mobile Satellite Service (MSS) System Characteristics

Category	Parameters	MCHI (Ellipso 2G)	Constellation II	CELSAT	TMI (CANSAT-M3)
Constellation	Orbit	Circular and Elliptical	Circular	Circular	Circular
	Inclination	(Note 1)	62° for 7 planes of 5 satellites each, Equatorial for 1 plane of 11 satellites	GSO	GSO
	# Satellites	26	46	1 (Initial) 3 (Total - Future); #1: 90° - 100° W, #2: 65° - 75° W, #3: 110° - 120° W	1; 106° - 112° W with 106.5° W preferred
	# Planes	5 (4 elliptical and 1 circular)	8	1	1
	Satellite Separation	(Note 1)		Longitudinal spread > 21°	N/A
	Altitude (km)	(Note 1)	2035 for 62° planes, 1965 for equatorial plane	35,750 (nom)	35,750 (nom)
Space Station Design	Antenna Type	Multiple Beam Antenna	Multiple Beam Antenna	Multiple Beam Antenna	Multiple Beam Antenna
	# Beams	127	32	480	72
	Polarization	Circular	RHCP	RHCP	RHCP
User Terminal Design	Antenna Type	Non-Directional	Non-Directional	Non-Directional	Non-Directional
	Receive G/T (dB/K)	Handheld: -25.4 Transportable: -14.0	-22.1	-26	-10 to -24
S-E Service Link Parameters	Access Scheme	FDMA/CDMA	CDMA	CDMA & TDMA	CDMA & SCPC/FDMA
	Frequency (GHz)	Uplink: 1.990 – 2.025 Dnlink: 2.165 – 2.200	Uplink: 1.980 – 2.025 Dnlink: 2.165 – 2.200	Uplink: 1.990 – 2.025 Dnlink: 2.165 – 2.200	Uplink: 1.990 – 2.025 Dnlink: 2.160 – 2.200
	Modulation	Data: BPSK Spread: QPSK & Offset QPSK	Offset QPSK		QPSK

Table 2-3 (Concluded): Representative Mobile Satellite Service (MSS) System Characteristics

Category	Parameters	Inmarsat (Horizons)
Constellation	Orbit	Circular
	Inclination	GSO
	# Satellites	4; #1: 20° E, #2: 110° E, #3: 170° W, #4: 90° W
	# Planes	1
	Satellite Separation	Function of which satellites considered
	Altitude (Km)	35,750 (nom)
Space Station Design	Antenna Type	Multiple Beam Antenna
	# Beams	120 to 300
	Polarization	LHCP
User Terminal Design	Antenna Type	Directional and Non-Directional
	Receive G/T (dB/K)	-16 to -6
S-E Service Link Parameters	Access Scheme	TDMA
	Frequency (GHz)	Uplink: 1.980 – 2.025 Downlink: 2.160 – 2.200
	Modulation	

	Borealis – 2G	Concordia – 2G
(1)	3 planes (all Elliptical)	2 planes (1 Elliptical and 1 Circular)
	5 satellites/plane	5 satellites in elliptical plane; 6 satellites in circular plane
	Elliptical (Apog: 7513.4 km, Perig: 674.3 km; Inc: 116.6°)	Elliptical (Apog: 7975.7 km, Perig: 4285.6 km; Inc: Equatorial) Circular (Alt: 7747.3 km)
	Spacing: 72°	Spacing: 72° (Elliptical), 60° (Circular)

(2) The Boeing MSS system is proposed to be used for the provision of communications, navigation, and surveillance services for global avionics commonly referred to as Aeronautical Mobile-Satellite (Route) Services. In this context, ATN refers to the Aeronautical Telecommunications Network and TIS refers to Traffic Information Services. ATN supports two-way communications while TIS is only a one-way, ground-to-satellite-aircraft broadcast link.

(3) The user terminal for the Boeing MSS system is an aircraft terminal.

3. Interference Criteria for MSS Downlink Interference into FS Receive Stations

TIA Bulletin TSB-10F (Interference Criteria for Microwave Systems) provides the interference criteria that are in use for frequency coordination within the fixed service in the US The implicit assumptions and level of detailed information that is built into the criteria of TSB-10F may not all be appropriate for sharing between MSS and FS systems. The objective of this section is to provide MSS/FS interference criteria at an equivalent level of performance protection to the fixed service while affording the maximum operational freedom to the mobile satellite service.

3.1 Background

A key characteristic of the interference from MSS satellites that must be accommodated is its time variability. The interference criteria in Bulletin TSB-10F were developed to address interfering signals with non-varying power. (Even in the case of an interferer using ATPC, coordination is conducted with these criteria by placing suitable requirements on the implementation of the power control.) This does not mean that the interfering signals from fixed service transmitters do not occur with time-varying levels at an interfered-with receiver, but rather, that the variations are independent of and less severe (milder) than the variations of the desired signal.

In the case of interference from non-GSO MSS satellites, there is a large component of variability in the received interference due to the regular motion of all the satellites in a uniform constellation. While these variations can be examined through computer simulation and modeling, heretofore there have been no appropriate US FS interference criteria to use as a measure of acceptability. In situations where the interference power is variable, the usual engineering practice has been to require conformance with both long-term and short-term interference criteria. Such an approach is taken in earth station coordination and in the ITU-R in sharing studies between the FS and the MSS. In this context, the interference criteria of Bulletin TSB-10F may be considered to be long-term criteria.

The long-term criteria are criteria that must be met by an interferer for all but 20 percent of the time. (While other percentages could be used, the 20 percent level has been used internationally by the fixed service for many years.) During the time that the interfering signal power exceeds the long-term criteria, it is expected to be statistically well behaved, and to exceed a threshold level significantly greater than the long-term level only very rarely. This higher interference threshold level is referred to as a short-term interference criterion and corresponds to a performance degradation not to be exceeded at the system level for more than some small percentage of time (typically much less than 1% of the time).

The following section provides the criteria that represent the maximum permissible levels of interference when coordinating MSS downlinks with respect to FS receiving stations.

3.2 Criteria for MSS Interference Into FS Receivers

The criteria for interference from MSS systems provided in the following sections are to be applied on a *per-link* basis, including multi-hop FS systems. Section 3.2.1 addresses MSS/FS interference criteria for analog FS links while section 3.2.2 addresses the interference criteria for digital FS links.

3.2.1 Analog Link Interference Criteria

For analog links, a further distinction is made between MSS-only interference noise power criteria and aggregate noise power criteria. As the name suggests, MSS-only interference noise power criteria applies to the additional interference noise power contribution that results from the MSS interfering signals. Aggregate noise power criteria, on the other hand, applies to the aggregate of thermal noise power and MSS interference noise power and takes into account multi-path fading and other sources of noise within the FS system.

Long- and short-term "MSS-only interference noise power" criteria are provided in Section 3.2.1.1 while long- and short-term "aggregate noise power" criteria are presented in Section 3.2.1.2.

3.2.1.1 Criteria for MSS-Only Interference Noise Power

The MSS-only interference noise power criteria for MSS/FS interference evaluations are shown pictorially in Figure 3-1. There are both long-term and short-term criteria that must be met. Recommended values for the long-term and short-term MSS-only interference noise power criteria are:

- Long Term[2]:

  X pW0p not to be exceeded for more than 20% of the time where X is defined as follows:

  a. For a FS route length greater than 400 km,

     X = 20 pW0p per 4 kHz at baseband

  b. For a FS route length less than or equal to 400 km (or for routes of unknown length)

     X = max {25, 250/n} pW0p per 4 kHz at baseband

[2] The long-term criterion of 20 pW0p for FS route lengths greater than 400 km was determined by linearly apportioning the 12-hop, 240 pW0p criteria identified in RR Appendix S5 (Resolution 46 (rev WRC-97), Annex 2) on a single-hop basis. The long-term criterion for FS routes less than or equal to 400 km was taken from Annex A of TSB-10F.

where n = number of hops

- Short Term: 50,000 pW0p per 4 kHz at baseband not to be exceeded for more than 0.0002% of the time

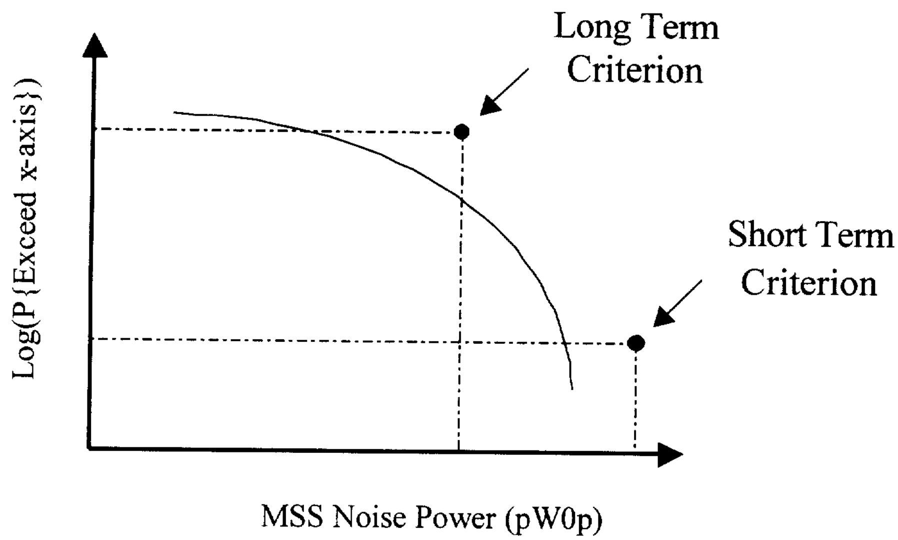

Figure 3-1 MSS-Only Interference Noise Power Criteria for Analog Links

3.2.1.2 Limits for Aggregate Noise Power

The aggregate noise power criteria for evaluations of MSS interference to an analog FS link are shown pictorially in Figure 3-2. As discussed further below, the three aggregate noise power thresholds (one long-term and two short-term thresholds) are assumed to exclude noise power generated by intermodulation within the FS system. The recommended values for the long-term and short-term aggregate noise power criteria are:

- Long Term: 150 pW0p per 4 kHz at baseband not to be exceeded for more than 20% of the time

- Short Term I: 50,000 pW0p per 4 kHz at baseband not to be exceeded for more than 0.002% of the time

- Short Term II: 1,000,000 pW0p per 4 kHz at baseband not to be exceeded for more than 0.0002% of the time

The long-term and short-term criteria were determined by linearly apportioning the 50-hop limits identified in Recommendation ITU-R F.393-4 on a single-hop basis. Specifically, for the long-term criterion, the power threshold of 7500 pW0p (ITU-R F.393-4) was divided by 50, yielding 150 pW0p, on a per-hop basis. For the short-term I and II criteria, the percentages of times (in ITU-R F.393-4) of 0.1% and 0.01% were divided by 50 to obtain 0.002% and 0.0002%, respectively.

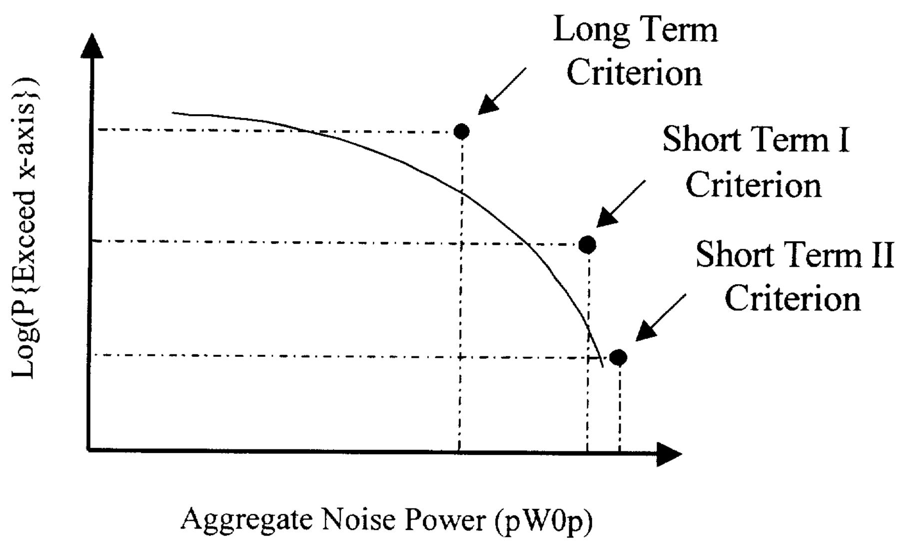

Figure 3-2 Aggregate Noise Power Criteria for Analog Links

Typically, a significant portion of the long-term aggregate noise power in the circuits at the terminating receiver of an analog FS system arises from intermodulation of desired signals within the FDM payload carried by the FS system.[3] However, inclusion of the intermodulation noise power component in calculations of the long-term aggregate noise power for an individual FS link would greatly complicate the analysis. Two approaches were considered for eliminating the need to calculate intermodulation noise power levels: (1) reduce the aggregate noise power threshold by a typical level of intermodulation noise power, or (2) assume the impact of intermodulation noise power contribution is offset by the shorter lengths of current systems. The latter approach was taken in setting these specified criteria. In particular, the aggregate noise power criterion of Recommendation ITU-R F.393-4 is specified for a reference hypothetical 2500 km FS system comprised of 50 hops. However, most analog 2 GHz FS systems have fewer than 50 hops, and it is assumed that the specified interference power can be applied equally to each of these. For comparison, a 12-hop reference system is assumed for assessing

[3] Intermodulation noise is assumed to comprise a negligible portion of the short-term aggregate noise power and need not be considered when applying the short-term criteria.

MSS interference into analog FS systems in Recommendation ITU-R IS.1143 and in Appendix S5 of the Radio Regulations.

3.2.2 Digital Link Interference Criteria

No specific numerical interference criteria have been developed in either the TIA or the ITU-R to specifically address short-term interference into digital receivers. The typical or default path design criteria for digital radios operating in this band is for a two-way path availability of 99.999%, although higher or lower levels are sought and achieved in practice. A potential difficulty with short-term interference levels lies in the possibility that if they are much higher than long-term levels, they could be strong enough to cause performance problems to a digital system even in the absence of any fading. Furthermore, only criteria pertaining to aggregate noise power are provided for digital links. Aggregate noise power in a digital FS system comprises thermal noise power and MSS interference noise power and takes into account multi-path fading.

The terms “link availability” and “link reliability” in an FS link are treated synonymously in this document; they are defined as the probability that the FS link fade depth will not exceed the link fade margin. Conversely, link “unavailability” is defined as the probability that the FS link fade depth will exceed the link fade margin, and it is simply 1 minus the link availability.

Using the definitions above, the digital link interference criteria are shown pictorially in Figure 3-3, in terms of a limit on link "unavailability" and mathematically as follows:

$$\text{"}\mathit{post\text{-}MSS}\text{" } \mathit{Link\ Unavailability\ Limit} = \max\left\{ \mathit{simple\ unavailability\ limit},\ \left(1+\frac{PDL}{100}\right)\left(\text{"}\mathit{pre\text{-}MSS}\text{" } \mathit{Link\ Unavailability}\right)\right\} \qquad \text{3-1}$$

As shown in Figure 3-3, the criteria comprise two regions referred to as the *simple unavailability region* and the *performance degradation region*, respectively. The threshold in the *simple unavailability region* takes the form of a *simple unavailability limit* that must be achieved for an FS link in the presence of MSS interference. It is applicable to FS links having an inherent or “pre-MSS” unavailability level (i.e., no MSS interference) better (i.e., smaller) than the cut over point identified in Figure 3-3 (i.e., to the left of the cut over point)[4]. For example, if an FS link were operating at an inherent unavailability level of 10^{-6} and the *simple unavailability limit* was set at 10^{-5} (corresponding to

[4] The use of a cut over value in Figure 3-3 is needed to account for sharing in situations in which the pre-MSS FS link unavailability level is very close to the *simple unavailability limit*.

a "reliability" of 0.99999), then the FS link unavailability in the presence of MSS interference is limited to a maximum level equal to the *simple unavailability limit* of 10^{-5}.

The threshold in the *performance degradation region* takes the form of a maximum percentage of FS availability degradation, referred to as the *performance degradation limit* (PDL), that the MSS interference is allowed to cause to the FS link . Specifically, the PDL is specified as the percentage increase in unavailability due to MSS interference. The *performance degradation region* is applicable to FS links having an inherent link unavailability equal to or worse than the cut over point identified in Figure 3-3 (i.e., equal to or to the right of the cut over point). For example, if an FS link were operating at an inherent unavailability level of 10^{-4} (corresponding to a "reliability" level of 0.9999) and the *simple unavailability* and *performance degradation limits* were set at 10^{-5} and 25%, respectively, then the FS link unavailability in the presence of MSS interference is limited to a maximum level of 1.25×10^{-4}. For this example, the maximum unavailability level was calculated as follows:

$$\text{Maximum unavailability level} = (1 + \text{PDL}/100)(10^{-4}) = 1.25 \times 10^{-4} \qquad \text{3-2}$$

where the PDL is given as a percentage. This example corresponds to a minimum link reliability level of 0.999875.

Recommended values for the *simple unavailability* and *performance degradation limits* are[5]:

- $(5x10^{-5})/n$ *simple unavailability limit* where "n" is the number of hops in the end-to-end system (corresponds to an end-to-end reliability of 0.99995). For system lengths less than or equal to 400 km, the *simple unavailability limit* is relaxed to 10^{-5}.

  Example 1: For a 400-km system having 10 hops, the per-hop *simple unavailability limit* would be the relaxed value of 10^{-5} (corresponds to a per-hop reliability of 0.99999).

  Example 2: For a 1,200-km system length having 30 hops, the per-hop *simple unavailability limit* would be $(5x10^{-5})/30$ or $1.667x10^{-6}$ (corresponds to a per-hop reliability of 0.9999983).

- 25% for the *performance degradation limit, assuming an I/N ratio of less than or equal to 20 dB.*

[5] The approach for calculating the *simple unavailability limit* is consistent with section 4.2.2 of Bulletin TSB-10F.

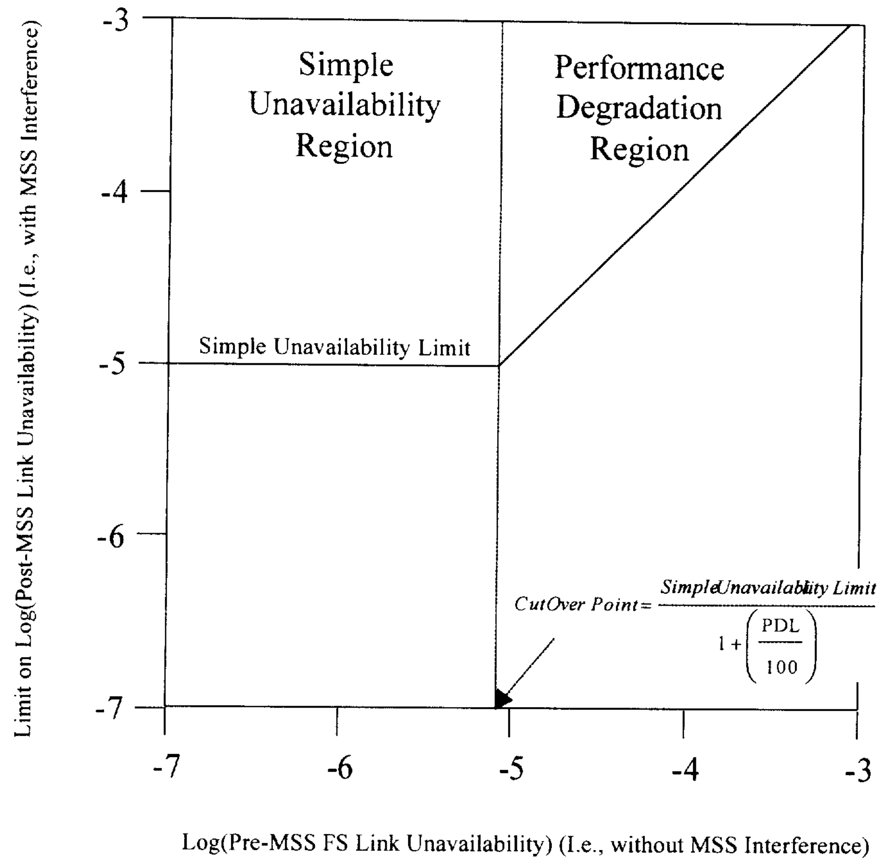

Figure 3-3 Aggregate Noise Power Interference Criteria for Digital Links

3.3 Multiple Exposure Allowance for Multiple MSS Systems

The interference criteria presented in this chapter for the "aggregate noise power" cases were derived assuming that only one MSS system is producing interference at the FS receiver. In some cases, however, an FS system may receive interference from more than one MSS system. This section explains how to deal with such situations. It should be noted that the method given here assumes that all MSS assignments are known. Thus, if an MSS system has been coordinated based on an assumed MSS band plan, and that band plan subsequently changes (for example, by the introduction of a new MSS system), the previously coordinated systems may have to be re-coordinated.

3.3.1 Multiple Interference Scenarios

There are basically three scenarios where a particular FS receiver channel may experience interference from two or more MSS systems.

Scenario 1: several MSS systems operate on a co-frequency, co-coverage basis. This might occur only for CDMA systems, which may in any case be designed to operate at PFD levels lower than the PFD thresholds for coordination.[6]

Scenario 2: the bandwidth of an FS receiver straddles the non-overlapping, assigned bands of two MSS systems, as shown in Figure 3-4.

Scenario 3: a combination of the two above scenarios.

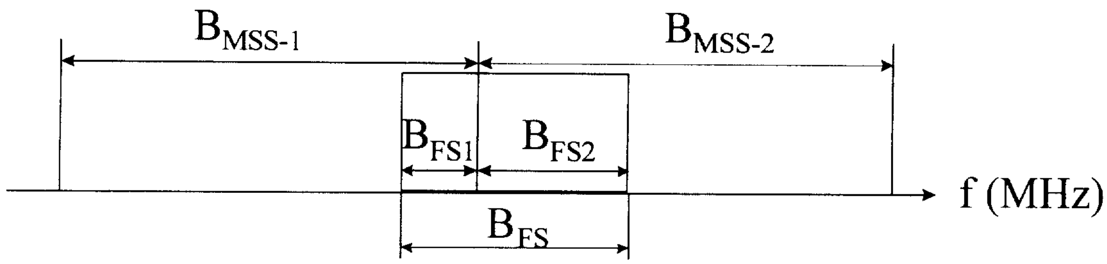

Figure 3-4 Multiple interference to an FS receiver from two MSS systems in adjacent bands.

3.3.2 MEA Alternative Methods of Computation

Three theoretical methods have been considered for taking multiple interference exposures into account.

Method 1: include all relevant MSS systems in the interference calculation methodology.

Method 2: apportion the criteria between all relevant MSS systems (and do the calculation for each MSS system separately).

Method 3: "inflate" the MSS interference power to account for the existence of multiple interfering MSS systems.

As the coordination procedure assumes a bilateral negotiation process between one MSS operator and FS operators, the interference calculation methodology in this TSB has been developed for a single MSS system. Thus, Methods 2 and 3 are the only possible ones.

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[6] Studies have shown that up to four MSS systems using CDMA can share the same frequencies under ideal circumstances (e.g., all such systems operating at about the same PFD level). In other bands, however, CDMA systems operate at PFD levels below the coordination threshold (e.g., 2483.5 – 2500.0 MHz). Studies have also shown that non-CDMA MSS systems (e.g., TDMA systems) _cannot_ operate with overlapping coverage areas on the same frequencies as other MSS systems---either other TDMA or even CDMA systems.

Method 3 is similar to Method 2, but instead of apportioning the criteria, the actual interference is appropriately inflated to account for multiple systems. If the end results of the MSS interference analysis (i.e., the quantity that is directly compared to the criteria), then the effect of scaling that quantity up (Method 3) would be the same as scaling the criteria down (Method 2). However, by scaling the interference power upward, the adjustment is performed at a different point in the analysis (except in the case of the MSS-only analysis for analog FS receivers, where the final result of the analysis *is* the interference power). FS system noise should *not* be scaled, of course. In contrast, in Method 2, the FS noise would actually be counted multiple times (once for each MSS system being coordinated). Thus, Method 3 most accurately takes multiple interference into account and *is the recommended approach in this TSB.*

Scaling of the MSS interference power is done most simply by shifting the power scale of the PDF of interference. A more refined method is to convolve the interference PDF with itself (N-1) times, where N is the number of systems. This approach is analytically correct, assuming independence of the systems, and it causes the low-probability part of the curve to be shifted in probability--which is what would be expected with multiple interferers. Both these approaches may be used for different parts of the recommended MEA procedure given in the next section.

3.3.3 Recommended MEA Procedure (Based on Method 3)

MSS systems sharing *the same* band (Scenario 1) are given equal interference allowances. It is necessary to allocate the interference between MSS systems using *adjacent band* segments (Scenario 2) in proportion to the overlap of the segment with the FS radio-frequency channel. The generic scenario (Scenario 3) can be dealt with by combining these two principles, which gives rise to the following step-by-step procedure:

Step No.

1. For an MSS system operating in the band B_{MSS-X}, reduce the power scale of the original MSS interference PDF by the factor: (B_{FS}/B_{FSx}), where B_{FS} is the FS receiver bandwidth (MHz) and B_{FSx} is the amount by which the MSS system frequency assignment overlaps the same FS RF receiver bandwidth (MHz). See Figure 3-4.

2. Convolve the new interference PDF derived in the previous step with itself (N-1) times, where N is the number of co-frequency MSS systems in the band, B_{FSx}.

3. Run the methodology in Section 4 for the "aggregate noise power" calculations with the new interference PDF.

4. Compare the results with the criteria in Section 3.2.